

Rapid survey of bats (Chiroptera) in the Atlantic Forest in eastern Sergipe, Brazil: unexpected diversity in a fragmented landscape

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Abstract

Despite advances in recent decades, the Atlantic Forest of northeastern Brazil is still one of the least studied regions of the country, regarding, for instance, the bat fauna. The present study reports on the results of a rapid survey of the bat fauna of a fragmented landscape in the Atlantic Forest of eastern Sergipe, in the legal forest reserve of Fazenda Santana, a commercial sugarcane plantation located in the adjoining municipalities of Japoatã and Pacatuba. We recorded 272 bats belonging to 23 species and four families, from which 265 individuals from 18 species from two families (Phyllostomidae and Vespertilionidae) were captured in the mist-nets, and seven individuals of six species from four families (Emballonuridae, Molossidae, Phyllostomidae and Vespertilionidae) were recorded during the active searches. This species richness was higher than that found in previous studies in the Atlantic Forest of northeastern Brazil. *Lasiurus blossevillii* and *Micronycteris minuta*

were recorded in Sergipe for the first time, increasing to 57 the number of bat species known to occur in this state. The use of alternative strategies (such as active search and sampling one night per point, seeking to areas with greater availability of resources) in rapid surveys may contribute to the compilation of a more robust sampling, reinforcing the usefulness of this approach for the inventory of the bat fauna of a given region.

Keywords

Lasiurus blossevillii, *Micronycteris minuta*, new records, sugarcane

Introduction

The Brazilian Atlantic Forest is a biodiversity hotspot, considered to be one of the world's most threatened biomes (Mittermeier et al. 2004; Varjabedian 2010). This biome initially covered an area of well over a million square kilometers (Muylaert et al. 2018). The reduction of its original cover to among 11–16% (in different regions) (Ribeiro et al. 2009) resulted in the ongoing loss of innumerable plant and animal species, including many endemic taxa (Paglia et al. 2012; ICMBio 2018). The northern extreme of the Biome (up to 15°S), which encompasses the Northeastern region of Brazil, has suffered the highest rates of deforestation and habitat fragmentation (IBGE 2016).

Additionally, the Atlantic forest of Northeast Brazil is still one of the least studied areas of the country (Bernard et al. 2011). Despite advances in recent decades, the lack of knowledge concerning the real patterns of diversity and distribution of some taxa, such as the bat fauna (e.g., Falcão et al. 2005; Mikalauskas 2005; Faria et al. 2006; Percequillo et al. 2007; Rocha et al. 2010; Brito and Bocchiglieri 2012), partially results in the underestimation of the current damage in the diversity caused by land-use change and native habitats degradation.

In the Atlantic forest, bats (Chiroptera) are the second most diverse mammalian order after Rodentia (Reis et al. 2007). Up to now, 182 bat species have been recorded in Brazil, representing 69 genera in nine families (Nogueira et al. 2018), which makes Brazil the second country with the most diverse bat fauna in the Neotropical region (Díaz et al. 2016). From those, approximately 117 species are known to occur in the Atlantic forest (Varzinczak et al. 2015). Bats are considered to play an important role in the ecology of forests, in particular as pollinators and seed dispersers (Lobova et al. 2009; Peracchi et al. 2011). They are fundamentally important for the regeneration of degraded areas (Dumont 2003; Bredt et al. 2012). Some species are also sensitive to habitat disturbance (Aguirre et al. 2003), making them useful as indicators of environmental quality (Fenton et al. 1992; Jones et al. 2009).

In Sergipe, northeastern Brazil, less than 10% of its original Atlantic forest cover remains standing (Santos et al. 2013; Marques et al. 2017). Up to now, 55 bat species have been recorded in the state (see Bocchiglieri and Bezerra 2018; Rocha et al. 2017a, b, 2018; Soares et al. 2017). However, many areas have yet to be surveyed adequately, preferentially using combined methods already known

to be complementary, such as stratified or canopy mist-nets (see Pech-Canche et al. 2011), ultrasound acoustics (see Silva and Bernard 2017), and active search for diurnal shelters (see Simmons and Voss 1998).

Despite the high difference in the sampling effort among studies that aim to inventory bat species richness and composition in each study site, the majority of the available studies have used mist-netting in monthly samples along the year (see Muylaert et al. 2017). Longitudinal inventories require a larger investment of human effort, finance, and logistics, commonly being executed in Protected Areas, since these areas usually offer some support (eg., lodgings, laboratories and drinking water). Conversely, rapid inventories (widely applied in environmental licensing in Brazil) are designed to sample a great data volume, as large as possible, in a short time interval, rarely higher than two weeks (PA Rocha, pers. comm.). When well-executed, therefore, rapid surveys are reliable to survey and inventory the richness and composition of bat species in a landscape at a much lower cost, mainly when using complementary sampling methods. Here we report the results of a rapid survey of the bat fauna of a fragmented landscape surrounded by a sugarcane plantation in the Atlantic forest of eastern Sergipe. In addition, we present the first record for the state of Sergipe for two bat species, highlighting the importance of surveying new sites even in rapid inventories.

Material and methods

Study area

The present study was conducted in the legal forest reserve of Fazenda Santana (600 ha of forest fragments; 10°32'07"S, 36°45'54"W), a sugarcane plant and farm located along the municipalities of Japoatã and Pacatuba, state of Sergipe (Fig. 1). The study area is a mosaic mainly composed of seasonal semideciduous Atlantic forest fragments, mainly represented by primary and secondary stages, with a small portion of riparian forest, complemented by enclaves of Restinga (Farias 2013; Authors pers. obs.). The fragments are set within a matrix of a large commercial plantation of sugarcane (*Saccharum* sp.) on an industrial scale. According to Köppen's classification, the local climate is *As* (Kottek et al. 2006; Alvares et al. 2013): Tropical Megathermal with a dry season in the summer. The annual rainfall ranges between 1,000 and 1,400 mm, with an average temperature between 22.7 °C and 26.5 °C (Aragão et al. 2013).

Data collection

We conducted the samplings over 10 consecutive nights, between October 19th to 28th, 2016. The bats were captured using mist-nets (12 nets of 12 m × 3 m; totaling 144 m on each transect) set at ground level, which we translocated at the end of each sampling night to cover eight transects established in different fragments of

the semideciduous seasonal forest within the mosaic (Fig. 1). During each sampling night, we opened the mist-nets from 18:00 h to 00:00 h, checking every 30 minutes. Captured bats were placed in cloth bags, and subsequently still in the field were identified according to Gardner (2007) and Díaz et al. (2016).

Complementarily, we conducted nonsystematic samplings through active searches during the daytime, investigating existing trails looking for feeding perches, possible natural shelters (dead trees, and tree holes), and human-made constructions (mainly abandoned buildings) within the Fazenda Santana. Eventually, natural shelters were opportunistically found by the research team during live trapping reviewing for small mammals. Whenever we found the shelters, we captured the bats using a net-gear trap (puçá), and/or a mist-net section positioning them in the opening of the shelters, as well as capturing the animals with the aid of a large tweezer when animals were confined in small spaces, such as between roof tiles. We collected voucher specimens of each sampled species (by systematic or nonsystematic samplings) that we deposited in the mammalian collection of the Laboratory of Conservation Biology (LBC) of the Federal University of Sergipe in São Cristóvão, Brazil (Appendix I). Specimens were collected under the permit SISBIO 7034-1.

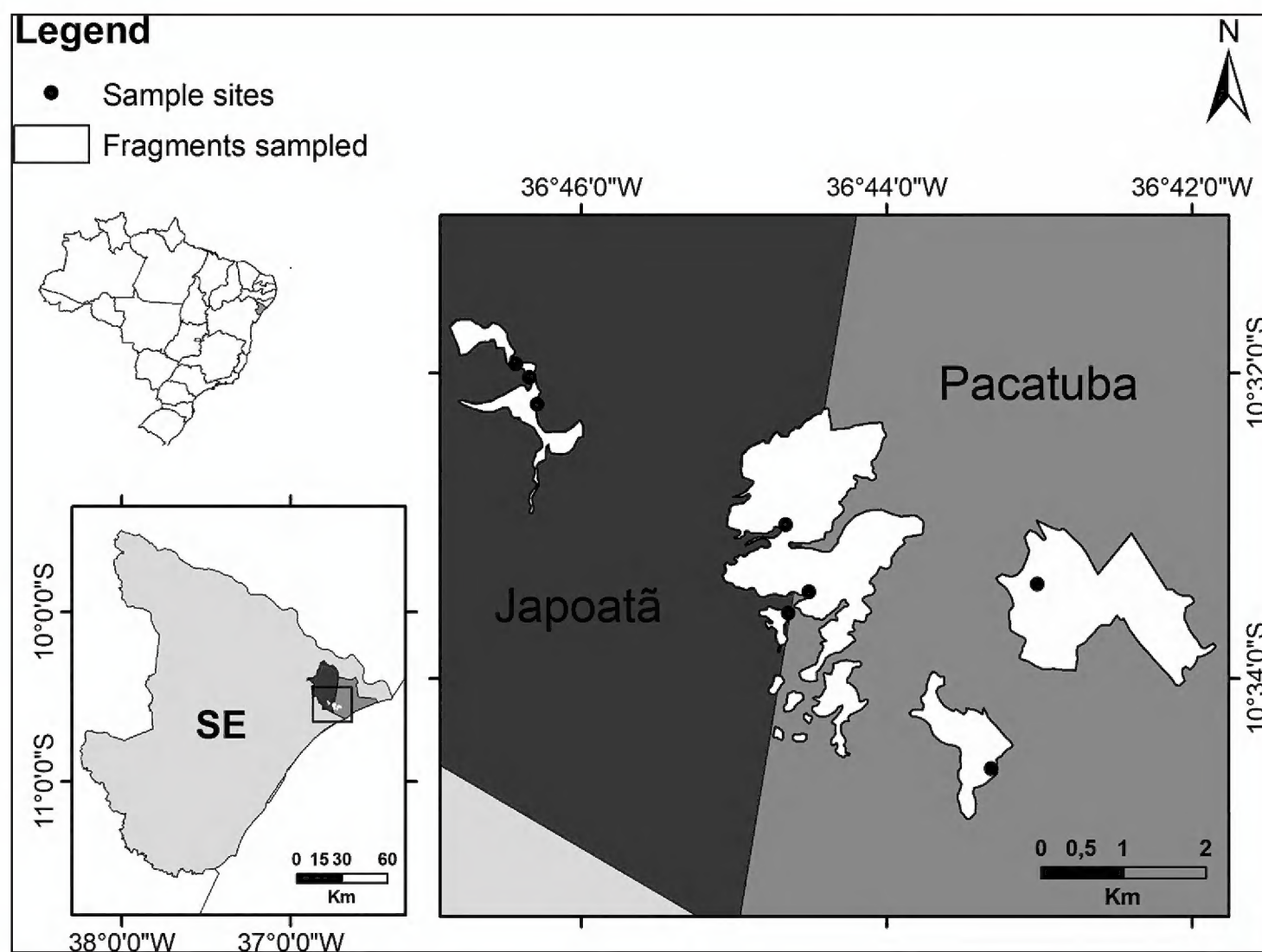


Figure 1. Sampling sites at which bats were collected in mist-nets in the fragments of Atlantic forest on Fazenda Santana, owned by the Brazilian Alcohol and Sugar Company (CBAA), in the municipalities of Pacatuba and Japoatã in Sergipe, northeastern Brazil.

Data analysis

The nomenclature we adopted followed Nogueira et al. (2018). We calculated the sampling effort according to Straube and Bianconi (2002), while the species richness was based on the estimator Jackknife 1, and calculated on EstimateS 9.0 (Colwell 2005) based on 1,000 iterations (see Colwell and Coddington 1994). At last, all the species were classified by their feeding guild, as defined by Kalko et al. (1996), with six trophic guilds being considered, namely frugivore, insectivore, omnivore, nectarivore, carnivore, and hematophagous. Sampling effort and species richness were run only to systematically sampled data, while the species recorded during the active searches were considered only to the species inventory and listing.

Results

After 25,920 h/m² of mist-netting sampling effort, we captured 265 individuals belonging to 18 species from two families (Phyllostomidae and Vespertilionidae). (Table 1; Fig. 2). Through the complementary active search, we sampled an additional seven individuals belonging to six species from four families (Emballonuridae, Molossidae, Phyllostomidae and Vespertilionidae) (Table 1; Fig. 3). Five species from two families were recorded only by active searches, representing 21.7% of the total richness, 23 species (Fig. 3). Through the systematic mist-netting, we sampled ap-

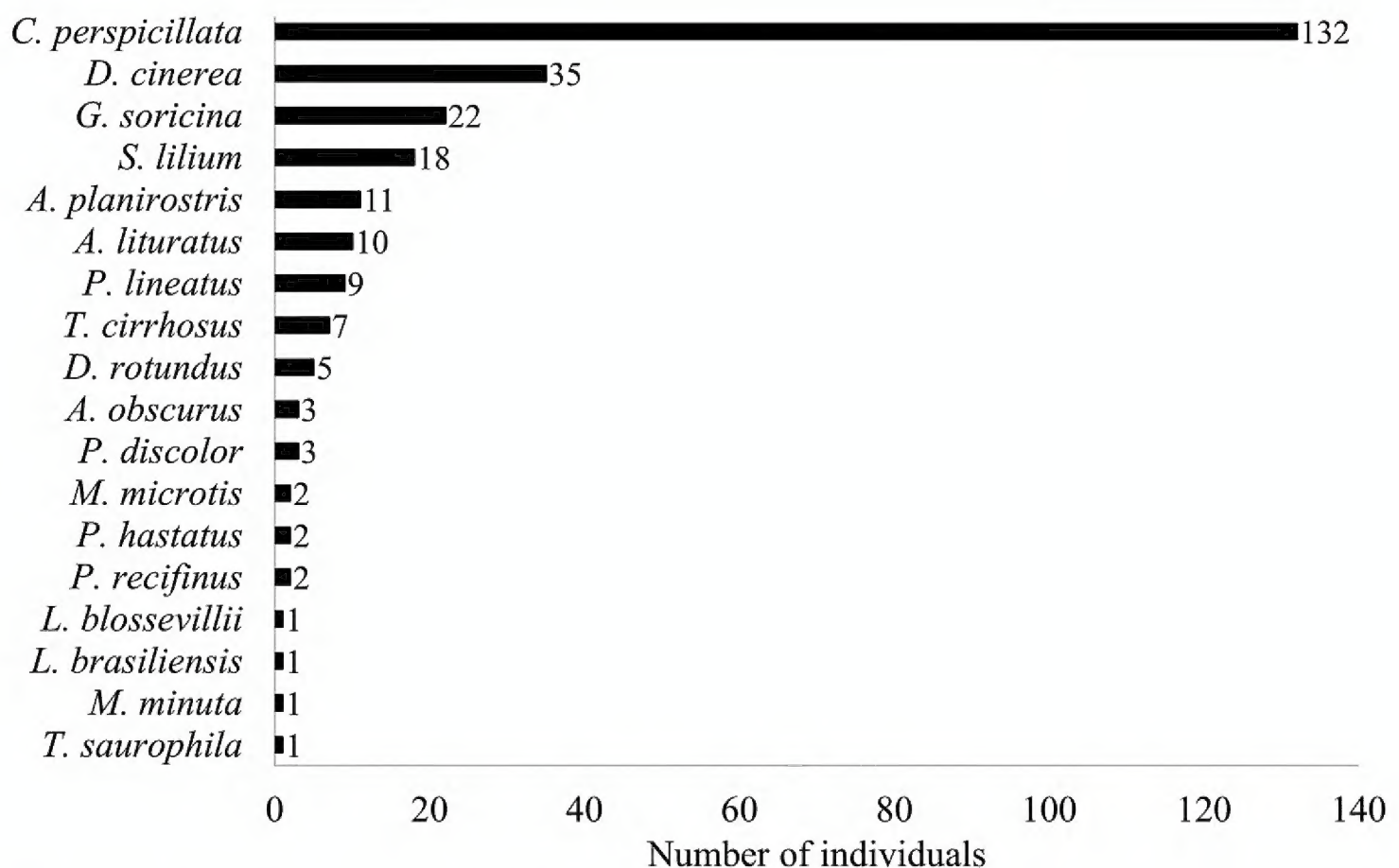


Figure 2. Relative abundance of each bat species recorded (using mist-nets) in the fragments of Atlantic forest on Fazenda Santana, in the municipalities of Pacatuba and Japoatã in Sergipe, northeastern Brazil.

Table 1. Bat species recorded in the in the fragments of Atlantic Forest on Usina Santana, owned by the Brazilian Alcohol and Sugar Company (CBAA), in the municipalities of Pacatuba and Japoatã in Sergipe, northeastern Brazil; abundance and trophic guilds; * – New record for the Brazilian state of Sergipe. A/S: Active Searches; M/N: Mist-Netting; Net’s (%): Relative Abundance in mist-nets.

Taxon	Number of individuals		Net's (%)	Guild
	A/S	M/N		
Emballonuridae				
Emballonurinae				
<i>Peropteryx leucoptera</i> Peters, 1867	2			Insectivorous
<i>Peropteryx macrotis</i> (Wagner, 1843)	1			Insectivorous
Molossidae				
Molossinae				
<i>Molossus molossus</i> (Pallas, 1766)	1			Insectivorous
Phyllostomidae				
Phyllostominae				
<i>Lophostoma brasiliense</i> (Peters, 1866)		1	0.4%	Insectivorous
<i>Phyllostomus discolor</i> Wagner, 1843		3	1.1%	Omnivorous
<i>Phyllostomus hastatus</i> (Pallas, 1767)		2	0.8%	Omnivorous
<i>Tonatia saurophila</i> Koopman & Williams, 1951		1	0.4%	Insectivorous
<i>Trachops cirrhosus</i> (Spix, 1823)		7	2.6%	Carnivorous
Carolliinae				
<i>Carollia perspicillata</i> (Linnaeus, 1758)		132	49.8%	Frugivorous
Desmodontinae				
<i>Desmodus rotundus</i> (É. Geoffoy, 1810)		5	1.9%	Hematophagous
Glossophaginae				
<i>Glossophaga soricina</i> (Pallas, 1766)	1	22	8.3%	Nectarivorous
Micronycterinae				
<i>Micronycteris microtis</i> Miller, 1898		2	0.8%	Insectivorous
<i>Micronycteris minuta</i> (Gervais, 1856)*		1	0.4%	Insectivorous
Stenodermatinae				
<i>Artibeus lituratus</i> (Olfers, 1818)		10	3.8%	Frugivorous
<i>Artibeus obscurus</i> Schinz, 1821		3	1.1%	Frugivorous
<i>Artibeus planirostris</i> (Spix, 1823)		11	4.2%	Frugivorous
<i>Dermanura cinerea</i> Gervais, 1856		35	13.2%	Frugivorous
<i>Platyrrhinus lineatus</i> (É. Geoffoy, 1810)		9	3.4%	Frugivorous
<i>Platyrrhinus recifinus</i> (Thomas, 1901)		2	0.8%	Frugivorous
<i>Sturnira lilium</i> (É. Geoffoy, 1810)		18	6.8%	Frugivorous
Vespertilionidae				
Vespertilioninae				
<i>Myotis lavalii</i> Moratelli, Peracchi, Dias & Oliveira, 2011	1			Insectivorous
<i>Myotis riparius</i> Handley, 1960	1			Insectivorous
<i>Lasiurus blossevillii</i> (Lesson & Garnot, 1826)*		1	0.4%	Insectivorous
Total	7	265	100%	

proximately 77% (S = 18) of the estimated richness (S = 23.4 ± 1.99), considered as significantly different according to the Jackknife 1 estimator (Fig. 4).

Through the mist-netting, specimens of the family Phyllostomidae were the most captured (N = 264; 99.6%), with also the higher number of species (S = 17; 94.4%), and a single vespertilionid species (*Lasiurus blossevillii*) being captured. Among the phyllostomids, the Stenodermatinae was the subfamily with the high-

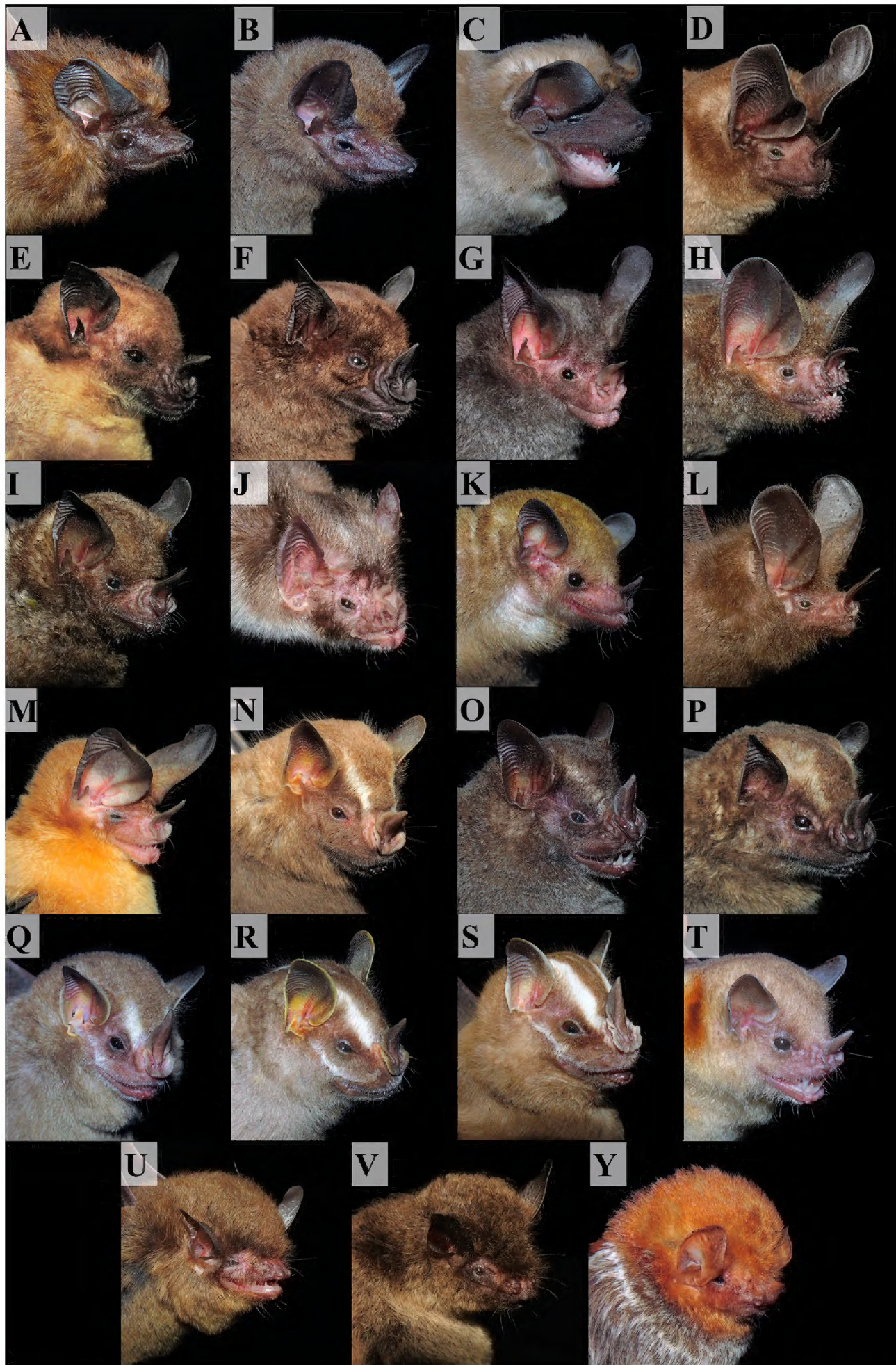


Figure 3. Bat species recorded in the fragments of Atlantic forest on Usina Santana, owned by the Brazilian Alcohol and Sugar Company (CBAA), in the municipalities of Pacatuba and Japoatã in Sergipe, northeastern Brazil. **A** *Peropteryx leucoptera*; **B** *Peropteryx macrotis*; **C** *Molossus molossus*; **D** *Lophostoma brasiliense*; **E** *Phyllostomus discolor*; **F** *Phyllostomus hastatus*; **G** *Tonatia saurophila*; **H** *Trachops cirrhosus*; **I** *Carollia perspicillata*; **J** *Desmodus rotundus*; **L** *Glossophaga soricina*; **M** *Micronycteris microtis*; **N** *Micronycteris minuta*; **O** *Artibeus lituratus*; **P** *Artibeus obscurus*; **Q** *Artibeus planirostris*; **R** *Dermanura cinerea*; **S** *Platyrrhinus lineatus*; **T** *Platyrrhinus recifinus*; **U** *Sturnira lilium*; **V** *Myotis lavalii*; **X** *Myotis riparius*; **Y** *Lasiurus blossevillii*.

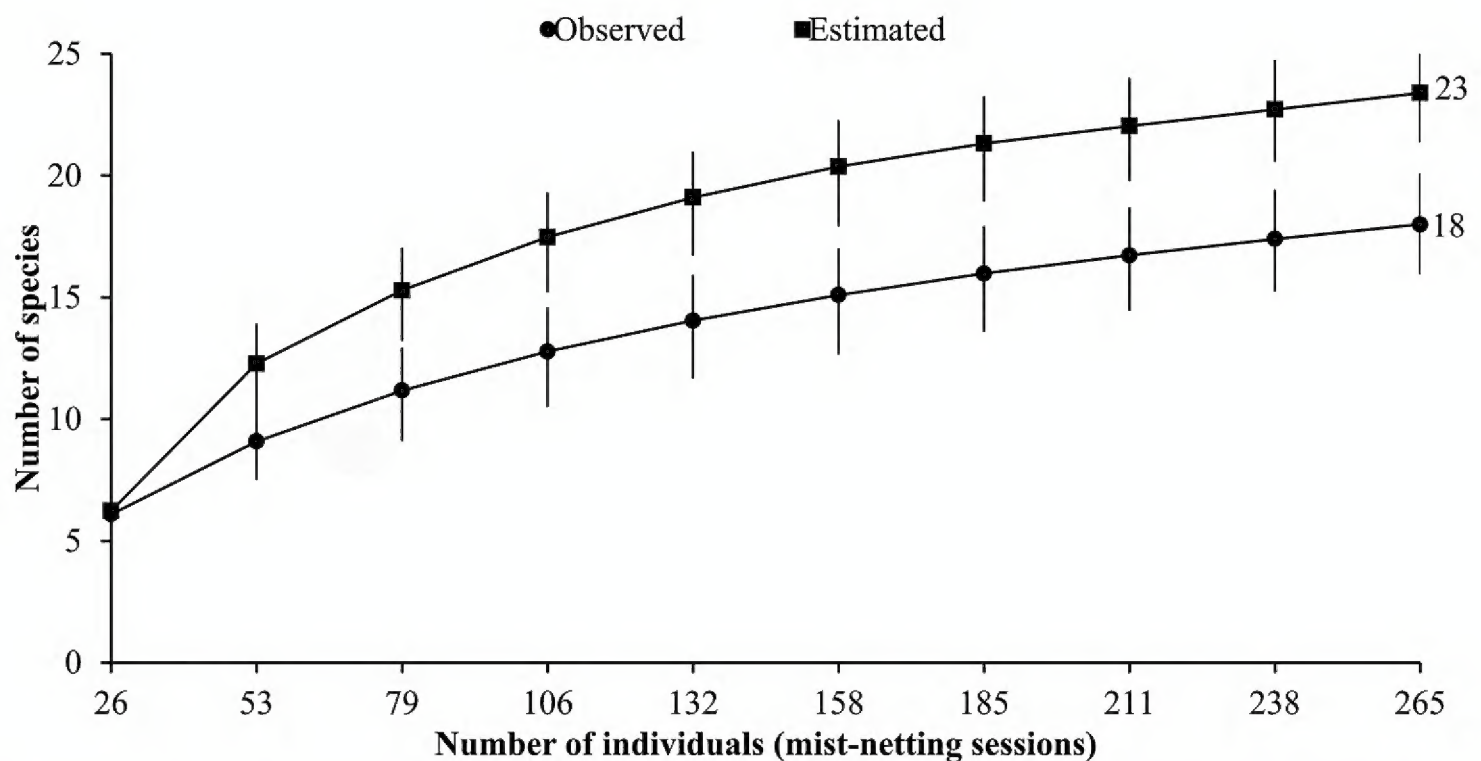


Figure 4. Observed and estimated (*Jackknife 1*) bat species richness in the fragments of Atlantic forest on Fazenda Santana, owned by the Brazilian Alcohol and Sugar Company (CBAA), in the municipalities of Pacatuba and Japoatã in Sergipe, northeastern Brazil.

est species richness, with seven species from four genera, while Carolliinae was the subfamily with the highest abundance, with 132 individuals of *Carollia perspicillata* (Linnaeus, 1758), representing half of all the individuals sampled by mist-netting. The five other most abundant species were *Dermanura cinerea* Gervais, 1856 ($n = 35$; 12.9% of the total), *Glossophaga soricina* (Pallas, 1766) ($n = 22$; 8.3%), *Sturnira lilium* (É. Geoffroy, 1810) ($n = 18$; 6.8%), *Artibeus planirostris* (Spix, 1823) ($n = 11$; 4.2%), and *Artibeus lituratus* (Olfers, 1818) ($n = 10$; 3.8%). The remaining species (see Table 1 and Fig. 2 for details) were relatively rare, with no more than nine individuals. The capturing of *Lasiurus blossevillei* (Lesson & Garnot, 1826), and *Micronycteris minuta* (Gervais, 1856) represent the first records in the Brazilian state of Sergipe.

The emballonurids *Peropteryx leucoptera* Peters, 1867, and *Peropteryx macrotis* (Wagner, 1843), the molossid *Molossus molossus* (Pallas, 1766), and the vespertilionids *Myotis lavalii* Moratelli, Peracchi, Dias & Oliveira, 2011 and *Myotis riparius* Handley, 1960 were recorded only during active searches. *Peropteryx leucoptera* Peters, 1867 was captured by encountering its natural shelter in the middle of the forest, consisting of a crevice covered by a tangle of dead branches near the roots of a tree, on the lateral of a dry ravine. All the other species recorded during active searches were found in anthropogenic shelters (buildings).

Regarding the trophic guilds, the frugivores constituted the feeding guild with the highest species richness, ($S = 8$; 44.4% of the total), followed by insectivores ($S = 5$; 28.8%), and omnivores ($S = 2$; 11.1%). The carnivorous, nectarivorous, and hematophagous guilds were represented by a single species each. Frugivores were also more abundant, with 219 individuals being captured (83.0% of the total), followed by the nectarivores, with 22 individuals (8.3%), all representing a single species, *G. soricina*.

Discussion

The species richness recorded in the present study ($S = 23$) was higher than those found in previous studies in the Atlantic forest from northeastern Brazil, which recorded 13 (Falcão et al. 2005), 14 (Brito and Bocchiglieri 2012), 16 (both Mikalauskas 2005 and Rocha et al. 2017a), and 18 species (Rocha et al. 2010). The sampling effort applied during the present study may not be considered satisfactory, given that the cumulative species curve had yet to reach the asymptote. It is interesting to note, however, that the estimated species richness was similar to that recorded in the present study adding mist-nets and active search (*i.e.*, 23 species). Nonetheless, the relatively large number of species recorded is the result of combined sampling strategies, such as the nightly change in transect and the sampling of different habitats as much as possible (see Rocha et al. 2017a).

The most frequent species in the present study are from the family Phyllostomidae, which are the predominant and most abundant species in the majority of the bat inventories in the Atlantic forest using mist-netting (see Muylaert et al. 2017), reflecting the selective nature of this method (Gardner 2007; Peracchi et al. 2011). In particular, vespertilionids, molossids and emballonurids have a well-developed echolocation system, which helps them to detect and avoid mist-nets (Fenton et al. 1992). In this sense, complementing the mist-netting, the use of ultrasound detectors is essential to access the richness of non-phylllostomid bats (Silva and Bernard 2017), providing a better understanding of the chiropterofauna of a landscape.

Two of the species recorded here, *L. blossevillii* and *M. minuta*, were recorded in Sergipe for the first time. The Southern Red Bat, *L. blossevillii*, is found throughout tropical South America, except Chile, most of Central America, and the western United States (Simmons 2005; Gardner 2007). The species is widely distributed in Brazil, where it has been recorded in 14 different states (Gardner 2007; Tavares et al. 2008), including Ceará (Piccinini 1974; Willig 1983), Alagoas (Sousa et al. 2004), Pernambuco (Sousa et al. 2004) and Paraíba (Dias et al. 2010), all located in the Northeast Region. The record from Sergipe is the first one within a gap of 1,100 km in the Atlantic Forest, between the records from the southern states of Alagoas (Sousa et al. 2004) and Espírito Santo (Ruschi 1954).

Micronycteris minuta is also found in Central and South America (Gardner 2007). In northeastern Brazil, it has been recorded in the states of Ceará (Willig 1983), Piauí (Araújo et al. 1998), Pernambuco (Guerra 2007; Marinho-Filho and Reis 2007; Astúa and Guerra 2008; Silva and Marinho-Filho 2010; Leal et al. 2013a), Maranhão (Dias et al. 2007, 2009), Paraíba (Dias et al. 2010; Feijó and Langguth 2011; Leal et al. 2013b), and Bahia (Faria et al. 2006). The present record from Sergipe state falls within a gap of 700 km between southern Bahia and Pernambuco states. The species appears to be relatively common in disturbed forest and crop plantations, as in the present study area (Peracchi and Albuquerque 1993; Bernard and Fenton 2002; Sampaio et al. 2003).

The active searches conducted during the present study provided important complementary data, including species from two families (Emballonuridae and Molossidae) not recorded in the mist-nets. One of the species recorded during these

searches, *P. leucoptera*, is extremely rare in the Atlantic forest. The present record is only the fifth for the biome, and the second outside the Pernambuco Endemism Center (see Mikalauskas et al. 2014). Positioning mist-nets along different transects on consecutive nights was proposed by Larsen et al. (2007) and Marques et al. (2013). According to these authors, this strategy increases the sampling efficiency, given that bats can learn to identify and avoid the nets, and this could explain the richness in the present study. In this sense, using an expressive sampling effort in Amazon rainforest, Pedroso (2018) concludes that there is a significant decrease in the success of capturing mist-nets armed by consecutive nights in the same place. Shifting the position of the nets also contributes to the sampling of a greater number of microhabitats within a given study area (Esbérard 2006).

The present study indicated that the use of alternative sampling strategies in rapid surveys contribute to the compilation of a more robust inventory, reinforcing the usefulness of this approach for the understanding of the bat fauna of a given region. In addition, this study increased to 57 the number of bat species known to occur in the Brazilian state of Sergipe.

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Appendix I

Examined material: *Artibeus lituratus* (LBC 0088); *Micronycteris microtis* (LBC 0089; LBC 0090); *Dermanura cinerea* (LBC 0091; LBC 0092; LBC0093); *Carollia perspicillata* (LBC 0094; LBC 0095; LBC0096; LBC 0097); *Platyrrhinus lineatus* (LBC0098); *Sturnira lilium* (LBC0099; LBC0100; LBC0101); *Trachops cirrhosus* (LBC 0102); *Artibeus planirostris* (LBC0103); *Artibeus obscurus* (LBC 0104); *Glossophaga soricina* (LBC0105; LBC 0106; LBC 0107); *Molossus molossus* (LBC 0108); *Myotis lavalii* (LBC 0109); *Myotis riparius* (LBC 0110); *Peropteryx macrotis* (LBC 0111); *Peropteryx leucoptera* (LBC 0112; LBC 0113); *Lophostoma brasiliense* (LBC 0114); *Desmodus rotundus* (LBC 0115); *Phyllostomus discolors* (LBC 0116); *Phyllostomus hastatus* (LBC 0117); *Micronycteris minuta* (LBC 0118); *Lasiurus blossevillii* (LBC 0119); *Platyrrhinus recifinus* (LBC 0120; LBC 121); *Tonatia saurophila* (LBC 122).